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WATER RESOURCES STUDY, GRAND RIVER BASIN, IOWA AND MISSOURI. STUDY OF POTENTIAL NEEDS AND VALUE OF WATER STORAGE FOR MUNICIPAL, INDUSTRIAL, AND QUALITY CONTROL PURPOSES

Public Health Service
Kansas City, Missouri

November 1963

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(no LC number)

REPORT ON WATER SUPPLY AND QUALITY CONTROL ASPECTS OF THE GRAND RIVER BASIN (Iowa and Missouri)

Prepared for

DEPARTMENT OF THE ARMY

U. S. Army Engineer District

Kansas City, Missouri

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

NOVEMBER 1963

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I. INTRODUCTION

Authority

In a letter dated March 27, 1962 the District Engineer, U. S. Army Engineer District, Kansas City, Missouri, requested the Public Health Service to: "... review a previous report on the Grand River Basin (Missouri and Iowa), dated June 1961, in light of Public Law 87-88, approved 20 July 1961, and based on 100-year projection of prospective needs for municipal and industrial water supply and for the regulation of streamflow for pollution abatement and water quality control."

This study was made under the provisions of the Memorandum of Agreement between the Department of the Army and the Department of Health, Education and Welfare dated November 4, 1958, and the Federal Water Pollution Control Act, Public Law 84-660 as amended by Public Law 87-88.

Purpose and Scope

This study was made to determine the need for and value of storage for municipal and industrial water supply and streamflow regulation for quality control.

In order to present 100-year projections adequately it was necessary to rewrite portions of each section of the June 20, 1961 report. This report, therefore, supersedes the previous report and contains estimates of water requirements for the present and for the years 2010 and 2060.

Acknowledgments

This study was made with the cooperation of the following agencies:

1. U. S. Army Engineer District, Kansas City, Corps of Engineers.
2. Missouri Water Pollution Board, Jefferson City, Missouri.
3. Missouri Division of Health, Jefferson City, Missouri.
4. State of Missouri, Division of Geological Survey and Water Resources, Rolla, Missouri.
5. Missouri Conservation Commission, Jefferson City, Missouri.
6. Missouri Water Resources Board, Jefferson City, Missouri.
7. Iowa State Department of Health, Des Moines, Iowa.

II. SUMMARY AND CONCLUSIONS

Summary

1. Seven multipurpose reservoirs are proposed for the Grand River Basin. The reservoirs are planned for flood control, municipal water supply, pollution abatement, recreation, and fish and wildlife.

2. Economic projections were made for all or parts of the following counties: Iowa - Ringgold, Decatur, Union, and Adair; Missouri - Worth, Harrison, Mercer, Gentry, Grundy, Sullivan, DeKalb, Daviess, Livingston, Linn, Caldwell, Clinton, and Charlton. The areas studied are within the Grand River drainage basin.

3. The basic industries of the area in their order of importance are: agriculture, manufacturing, and mining.

4. The principal communities in the study area are in Missouri. Their 1960 population figures are: Chillicothe, 9,236; Trenton, 6,236; Brookfield, 5,694; Cameron, 3,674; and Bethany, 2,771. All other communities in the study area had 1960 population figures of less than 2,500.

5. Treatment of Chillicothe's sewage reduces the organic waste concentration from 11,000 population equivalent (P.E.) to 1,100 P.E. before discharging to Grand River. Treatment of Trenton sewage reduces the organic waste concentration from 17,700 P.E. to 4,170 P.E. before discharging to Thompson River. Treatment of Brookfield sewage reduces the organic waste concentration from 4,400 P.E. to 440 P.E. before discharging to a ditch that flows to Yellow Creek. Treatment of Cameron sewage reduces the organic waste concentration from 2,600 P.E. to 300 P.E. before discharging to a Branch of Shoal Creek. Treatment of Bethany sewage

reduces the organic waste concentration from 3,355 P.E. to 2,160 P.E. before discharging to East Branch of Big Creek.

6. Thirteen municipalities in the study area use wells for their water supplies and thirteen have reservoirs or impoundments. One uses water from the Grand River. See Exhibit No. 3.

Chillicothe uses water from the Grand River. Trenton has two reservoirs and pumps water from the Thompson River and Bethany can pump water from Big Creek when needed. Brookfield pumps water from Yellow Creek.

Conclusions

1. Population in the study area is expected to increase from 163,323 in 1960 to 170,000 by 2010, and 270,000 by 2060.

2. The urban sector of the population is expected to show a significant increase, rising from approximately 38,000 in 1960 to 75,000 in 2010 and 180,000 by 2060.

3. Based on the availability of water in the basin and projections of population and economic growth, the need for municipal and industrial water supply is expected to increase from four million gallons per day (mgd) at present to about 13 mgd by 2010 and 27 mgd by 2060.

4. The present needs for municipal and industrial water can be met by using the present water supply sources plus the proposed municipal water works facilities.

5. Considering the inadequacy and poor quality of the ground water in the area and the accessibility of the communities to the system of reservoirs, it is estimated that the municipal and industrial water requirements from the system of reservoirs will be 8.0 cfs (5.3 mgd) in 2010 and 19.0 cfs (12.7 mgd) by the year 2060.

6. Based on the area's projected growth, storage for water quality control is needed to provide regulated flows of 25 cubic feet per second (cfs) for the base period, 55 cfs by 2010 and 97 cfs by 2060.

7. The total average value of storage to provide the needed stream-flow regulation for quality control is estimated to be $136,200 annually.

III. DESCRIPTION OF PROJECT

Purposes

The reservoirs will be used for flood control, municipal water supply, and streamflow regulation for quality control, and will contribute to expansion of recreational opportunities, and preservation of fishing and hunting values in a large area.

Location

Seven reservoirs are considered in the present Grand River basin study. Their locations are as follows:

Reservoir Name	State	Counties	Stream
Pattonsburg	Missouri	Daviess, Gentry, DeKalb, Harrison	Grand River
Braymer	Missouri	Caldwell, Livingston	Shoal Creek
Trenton	Missouri	Grundy, Daviess, Harrison, Mercer	Thompson River
Mercer	Iowa-Missouri	Mercer (Mo.) Decatur (Iowa)	Weldon River
Linneus	Missouri	Linn, Sullivan	Locust Creek
Brookfield	Missouri	Linn	Yellow Creek
St. Catherine	Missouri	Linn	East Fork of Yellow Creek

Pertinent Data

Seven multipurpose reservoirs and various channel improvements and leveed floodways on the Grand River and its tributaries are proposed in this project. The two largest reservoirs considered are Pattonsburg with a conservation storage of 956,400 acre-feet,and Trenton with a conservation storage of 765,800 acre-feet.

The approximate river mile location of the reservoirs and storage allocations are given in Table No. III-1.

Hydrology

Streamflows in the study area are shown in Exhibit No. 2. The periods of record are from one to 39 years. For all the streams the flows vary from low flows of 0 to 10 cfs to high flows of 3,900 to 180,000 cfs. The Grand River near Sumner, Missouri has an average flow of 3,626 cfs for the 37 years of record. Extrapolations from available records indicate that the unregulated low flows shown in Table No. III-2 can be expected at the selected stations on the main stem.

Table No. III-2

	River Mile	Drainage Area Square Miles	2% Chance Frequency Low Flow 30 days	183 days
Gallatin, Mo.	G-96	2,350	3	10
Sumner, Mo.	G-40	6,880	11	30

Table No. III-1

Water Resources Development Plan of Improvement

Grand River Basin

Reservoir Name	Location* (River Mile)	Drainage Area (Square Miles)	Conservation Storage Acre-Feet	Flood Control Acre-Feet	Sediment Acre-Feet	Total Acre-Feet
Pattonsburg	G-96	2,234	956,400	1,430,000	333,600	2,720,000
Braymer	G-58, SC-19	390	215,800	299,500	58,200	573,500
Trenton	G-64, T-30	1,079	765,800	748,100	161,100	1,675,000
Mercer	G-64, T-28 W-35	427	235,800	326,000	63,900	625,700
Linneus	G-42, LC-23	546	302,100	407,700	81,600	791,400
Brookfield	G-32, YC-29	140	77,500	117,200	20,900	215,600
St. Catherine	G-32, YC-14 EYC-12	118	65,400	100,000	17,600	183,000
Total		4,934	2,618,800	3,428,500	736,900	6,784,200

* G-Grand River
SC-Shoal Creek
T-Thompson River
W-Weldon River
LC-Locust Creek
YC-Yellow Creek
EYC-East Fork Yellow Creek

Table No. III-1

Water Quality

Typical raw water analyses for the cities using surface supplies in the basin show that these waters have a mineral content that is within the limits of the Public Health Service Drinking Water Standards. The treated water analyses of the water supply at Chillicothe show total dissolved solids were 151 ppm, chlorides 9 ppm (Cl), sulfates 63 ppm (SO_4) and hardness 78 ppm as $CaCO_3$. The raw water analyses of the raw water at Trenton shows total dissolved solids were 258 ppm, chlorides 6 ppm (Cl), sulfates 42 ppm (SO_4), and hardness 194 ppm as $CaCO_3$. See Exhibit No. 4. Chillicothe uses water from the Grand River and Trenton uses water from the Thompson River.

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The study area includes all of the Grand River Basin. The Grand River rises in southwestern Iowa and flows in a southerly direction through northwestern Missouri to join the Missouri River at mile 252 near Brunswick, Missouri. All or parts of the following counties are included in the study area: Ringgold, Decatur, Union and Adair in Iowa: Worth, Harrison, Mercer, Gentry, Grundy, Sullivan, DeKalb, Daviess, Livingston, Linn, Caldwell, Clinton, and Chariton in Missouri. The Chariton River Basin is east of the study area, the Platte River Basin west of the area, and the study area is bordered on the north by the Des Moines River Basin.

General Features

The Grand River Basin comprises an area of 7,900 square miles, of which 78 percent is in northwestern Missouri and the remainder in southwestern Iowa. The flood plains along the main stem and major tributaries are broad and flat, which results in frequent flooding with slowly receding floodwaters.

In the study area there are wide fluctuations in temperature and rainfall. The maximum temperature of record is 116° F. at Chillicothe, Missouri, and the minimum temperature of record is 34°F. below zero at Greenfield, Iowa. The mean annual temperature is 53° F. The normal annual precipitation in the Grand River Basin is approximately 36 inches, with a maximum of 62.32 inches in 1961 and a minimum of 18.94 inches in 1934. About 70 percent of the annual rainfall occurs during the six-month growing season - April through September. 27, P.3/

The principal communities in the study area are in Missouri. Their 1960 population figures are: Chillicothe, 9,236; Trenton, 6,236; Brookfield, 5,694; Cameron, 3,674; and Bethany, 2,771. All other communities in the study area had 1960 population figures of less than 2,500.

V. ECONOMY

Present

In 1960, the study area's labor force contained 55,202 employees, of which 24,745 were employed in the basic industries (agriculture, mining, and manufacturing). Over 50 percent of the labor force was employed in the service establishments, such as transportation, public administration, and retail and wholesale trades. Shown in Table No. V-1 are employment data for the study area. 4/

Agricultural employment has decreased from 35,478 in 1940 to 19,835 in 1960. The number of farms has also decreased during this period. However, with technological advancements on the farm and farm consolidation, the dollar values in agricultural production increased from about $105 million in 1949 to about $148 million in 1959 (adjusted to the 1954 value of the dollar). Table No. V-2 shows agricultural trends for the study area. 6,7,8/

Table No. V-2

Agricultural Trends 6,7,8/ - Grand River Basin

1949 - 1954 - 1959*

	No. Farms	Cropland Harvested (Million Acres)	Value of Crops Sold (Million Dollars)	Value of Livestock & Livestock Products Sold (Million Dollars)	Value of All Products Sold (Million Dollars)
1949	26,133	2.0	16.5	88.6	105.1
1954	23,460	2.0	25.5	80.0	105.5
1959	20,237	1.9	30.0	112.7	142.7

*Adjusted to the 1954 value of the dollar.

Table No. V-1

Employment Data by Industrial Categories [4,5]

for the Grand River Basin

1940 - 1950 - 1960

	1940		1950		1960	
	Number	Percent of Labor Force	Number	Percent of Labor Force	Number	Percent of Labor Force
Farm	35,478	48.4	31,546	49.2	19,835	35.9
Forestry & Fisheries	3	-	15	-	8	-
Mining	526	.7	301	.5	202	.4
Manufacturing	1,912	2.6	3,039	4.7	4,700	8.5
Furniture, Lumber, Wood Products	131		164		178	
Primary Metals	46		19		32	
Fab. Metals, Mach., Veh., & Other durables	163		493		577	
Textile & Apparel	50		398		983	
Food & Kindred Products	576		715		1,310	
Printing & Publishing	473		591		741	
Chemical & Allied Prod.	23		44		59	
Other Non-durables	450		615		820	
TOTAL BASIC	37,919	51.7	34,901	54.4	24,745	44.8
TOTAL SERVICE	31,384	42.8	28,261	44.1	28,712	52.0
UNEMPLOYED	3,973	5.5	905	1.5	1,745	3.2
TOTAL LABOR FORCE	73,276	100.0	64,067	100.0	55,202	100.0
TOTAL POPULATION	216,937		188,572		163,323	

Manufacturing employment has been increasing steadily, rising from 1,902 in 1940 to 4,700 in 1960. The most significant increases being in the fabricating metal, food and kindred products, and textile and apparel categories. [4,5] The value added by manufacturers increased about 40 percent from 1949 to 1959. [9,10,11] The number of establishments during this period displayed little change, indicating an increase in the size of existing firms. Table No. V-3 depicts data for the Grand River study area.

Table No. V-3

Manufacturing Trends [9,10,11] - Grand River Basin

1948 - 1954 - 1958*

	Number of Establishments	Value Added by Manufacturers ($1,000)	Capital Expenditures ($1,000)
1948	105	8,349	**
1954	119	9,721	751
1958	112	11,670	923

*Adjusted to the 1954 value of the dollar.
**Data unavailable

Several minerals of economic importance are found in the study area. In order of importance they include stone, sand and gravel, and coal. Employment in the mining category has decreased from 526 in 1940 to 202 in 1960. A decline in coal mining operations has been largely responsible for this decrease. Table No. V-4 displays trends in the dollar value of minerals extracted for the study area. [12,13,14,15,16]

Table No. V-4

Value of Mineral Production[12,13,14,15,16]

Grand River Basin

1952 - 1960*
(Millions of Dollars)

	1952	1953	1954	1955	1956	1957	1958	1959	1960
Study Area	1.2	1.0	1.0	.7	1.7	1.6	1.8	1.1	1.3

*Adjusted to the 1954 value of the dollar.

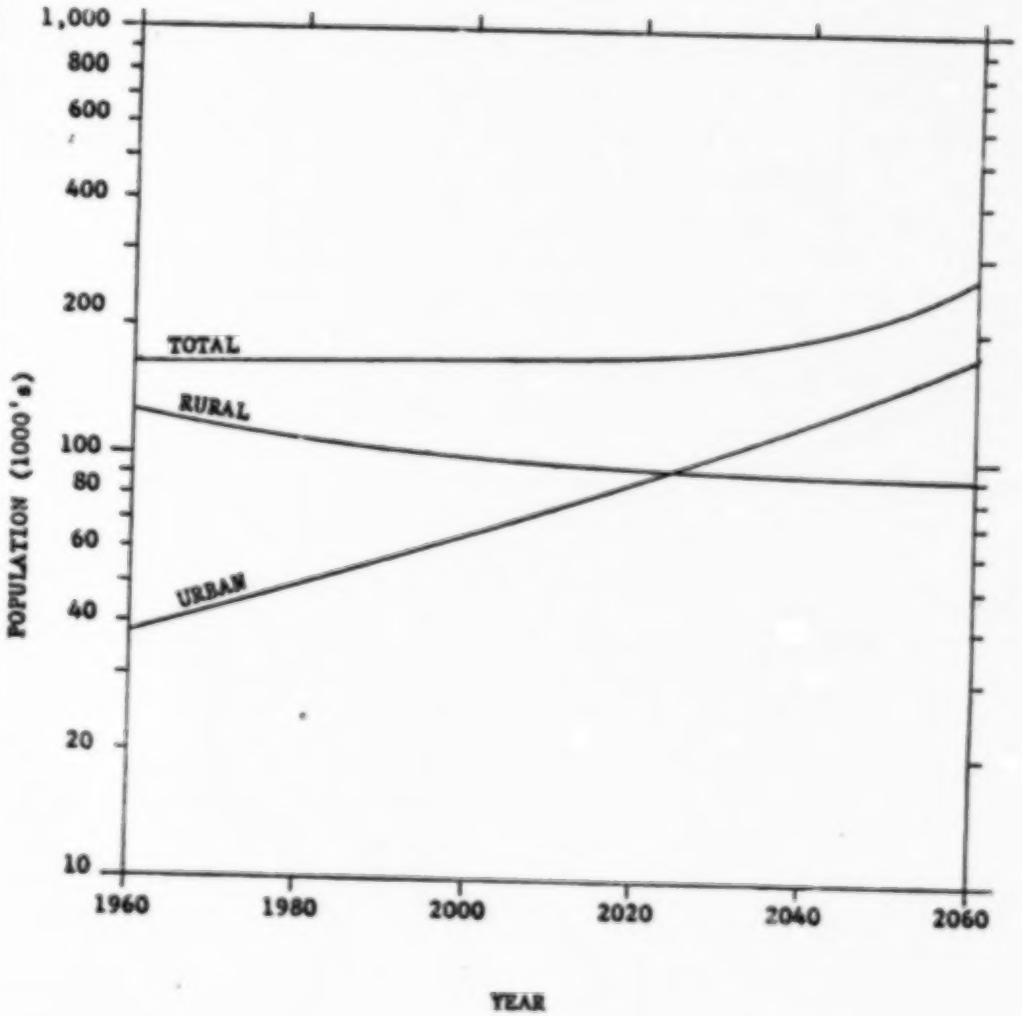
The total population of the study area has decreased from 258,473 in 1910 to 163,323 in 1960. During this period the urban portion has increased from 31,494 to 38,176, while the rural portion decreased severely from 226,979 to 125,147. Population data for the study area is presented in Table No. V-5.[1,2,3]

Future

Projected national and regional demands for the products capable of being produced in the study area is expected to stimulate the industrial activity. This increased industrial employment should reverse the downward total population trend.

The urban sector of the population should show a significant increase, rising from approximately 38,000 in 1960 to 75,000 in 2010 and 180,000 by 2060. The rural sector should decline gradually and reach 95,000 by 2010 and 90,000 by 2060. The total population of the study area is expected to be 170,000 by 2010 and 270,000 by 2060. Population projections are displayed in Figure No. V-1.

Agricultural employment is expected to continue its decline in the future and reach 12,000 by 2010 and 9,000 by 2060. However, the



GRAND RIVER BASIN

POPULATION PROJECTIONS
STUDY AREA

DEPT. OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

Figure No. V-1

Table No. V-5

Population Trends for the Grand River Basin

1910 - 1960

State	County	1910	1020	1930	1940	1950	1960
Iowa							
	Adair	14,420	14,259	13,891	13,196	12,292	10,893
	Decatur	16,347	16,566	14,903	14,012	12,601	10,539
	Ringgold	12,904	12,919	11,966	11,137	9,528	7,910
	Union	16,616	17,286	17,435	16,280	15,651	13,712
Missouri							
	Worth	8,007	7,642	6,535	6,345	5,120	3,936
	Gentry	16,820	15,634	14,348	15,359	11,036	8,793
	Harrison	20,466	19,719	17,233	16,525	14,107	11,603
	Mercer	12,335	11,281	9,350	8,766	7,235	5,750
	Sullivan	18,598	17,781	15,212	13,701	11,299	8,703
	Grundy	16,744	17,554	16,135	15,617	13,220	12,220
	Daviess	17,605	16,641	14,424	13,398	11,180	9,302
	DeKalb	12,531	11,694	10,270	9,751	8,047	7,226
	Caldwell	14,605	13,349	12,509	11,629	9,929	8,830
	Livingston	19,453	18,859	18,615	18,000	16,532	15,771
	Linn	25,253	24,778	23,339	21,416	18,865	16,815
(Part)	Chariton	11,752	10,884	9,794	9,012	7,472	6,360
(Part)	Clinton	4,018	4,348	4,447	4,664	4,455	4,680
TOTAL		258,473	251,692	230,406	216,937	189,572	163,323
URBAN		31,494	35,069	37,274	38,668	38,434	38,176
RURAL		226,979	216,623	193,132	178,269	150,138	125,147

study area is one of the major agricultural areas in the State and should increase its production by increased technology rather than additional employment. Table No. V-6 shows employment projections for the study area.

The number and size of manufacturing industries in the area should continue to increase in the future, particularly those that are oriented to the resource situation - food and kindred products and paper and allied products. In addition to these, there will be increases in those industries which supply the nearby markets - fabricating metals, machinery, textile and apparel, and printing and publishing. See Table No. V-6.

Employment in the mining category should increase slightly. An increased demand for sand and gravel and agricultural stone should increase the mining employment from 600 in 2010 to 900 in 2060. Extraction of coal is unlikely, since coal is at too great a depth (150 to 200 feet) for strip mining, and too thin (18 inches) for underground mining.

Table No. V-6

Projected Employment of the Labor Force
for the Grand River Basin

2010 - 2060

	2010		2060	
	Number	Percent	Number	Percent
Farm	12,000	20	9,000	10
Mining	600	1	900	1
Manufacturing	7,200	12	15,400	17
Fabricating Metals, Machinery, Vehicles, & Other Durables	1,000	-	2,500	-
Food and Kindred Products	2,000	-	3,500	-
Textile and Apparel	1,500	-	3,000	-
Printing & Publishing	1,000	-	2,500	-
Other Nondurables	1,000	-	2,500	-
Others	700	-	1,400	-
TOTAL BASIC	19,800	33	25,300	28
TOTAL SERVICE	38,400	64	62,000	69
UNEMPLOYMENT	1,800	3	2,700	3
TOTAL LABOR FORCE	60,000	100	90,000	100
TOTAL POPULATION	170,000		260,000	

VI. HYDROLOGY

Surface Water

Streamflows in the study area are shown in the Appendix, Exhibit No. 2. These records indicate that there is a wide variation in the flows of the Grand River and its tributaries. Extrapolations from available records indicate that the following unregulated low flows can be expected at selected stations on the main stem.

Table No. VI-1

	River Mile	Drainage Area	2% Chance Frequency Low Flow 30 days	183 days
Gallatin, Mo.	G-96	2,350 mi.	3 cfs	10 cfs
Sumner, Mo.	G-40	6,880 mi.	11 cfs	30 cfs

Maximum, minimum and average flows for the main stem at these points are shown in Exhibit No. 2. From the table of historical streamflows in the Appendix, it is evident that under present unregulated conditions most of the streams in the basin can be expected to be dry in times of drouth.

Typical raw water analyses for the cities using surface supplies in the basin show that these waters have a mineral content that is within the limits of the Public Health Service Drinking Water Standards. The analyses available indicate that the waters of the Grand River Basin are suitable for municipal and industrial water supply.

Ground Water

Ground water in the basin is of minor importance due to undependable supply and poor quality. Quantities necessary for municipal and industrial supplies cannot be obtained from the loess and glacial drift formations

underlying the area. The limited quantity that is available from these formations is high in minerals and other dissolved solids.

The majority of cities shown in Exhibit No. 3 as having wells, draw their water from the shallow river alluvium.

VII. MUNICIPAL AND INDUSTRIAL WATER SUPPLY NEEDS

Present

Chillicothe uses water from the Grand River. Brookfield pumps water from Yellow Creek, Trenton pumps water from the Thompson River, and when the water is needed Bethany can pump water from Big Creek. All other municipalities in the study area obtain their water from impoundments or wells. A majority of the well supplies come from shallow river alluvium. Most of the impoundments receive their water from small tributaries or surface runoff.

The municipalities in the study area use an average of about 80 gallons per capita per day (gpcd). See Exhibit No. 3.

Trenton Foods, Inc., located in Trenton, Missouri, is the major water using industry in the Grand River basin. The peak demand in 1961 was 0.9 mgd. 25/

Recent drought years, since the summer of 1952, have caused a marked increase in conservation of the waters in the basin. The water shortage in Bethany, Missouri became so critical in June 1956 that the President of the United States declared Bethany an emergency disaster area and called on the Civil Defense Administration to provide the municipality with an emergency water supply from nearby gravel pits. Later Bethany put in a line so that water can be pumped from Big Creek when needed. Brookfield and Trenton also suffered water shortages.

Brookfield put in an impoundment to improve the dependability of its water supply. Water to the impoundment comes from surface runoff and is supplemented by pumping water from Yellow Creek. Cameron put in a second reservoir to improve the reliability of its water supply.

Trenton plans to make extensive improvements in its water works facilities. The Area Redevelopment Administration has approved a grant for $548,000 and a loan of $962,000 for Trenton to be used for construction. A bond election will be held during the summer of 1963. The improvements at Trenton will include the following: storage reservoir; river intake, pump station and river supply main; reservoir intake, low service pump station and raw water supply main; 3.0 million gallon per day (mgd) treatment plant, clearwell storage and high service pump station; and distribution system and elevated storage. The estimated construction cost is $1,550,000. 25/

Typical chemical concentrations of municipal water supplies are shown in Exhibit No. 4. Ridgeway, Missouri has a deep well and the water contains high concentrations of chlorides (1152 ppm) and sulfates (1650 ppm). The deep well water supply of Leon, Iowa has a sulfate concentration of 1150 ppm and a chloride concentration of 170 ppm. The well supply of Stanberry, Missouri contains 573 ppm sulfates and 95 ppm chlorides. The chloride and sulfate concentrations of the other water supplies in the study area are less than the 250 ppm limit as recommended in the Public Health Service Drinking Water Standards.

Future

Trenton Foods, Inc. is the major water using industry in the basin, and no other municipality or industrial water user in the basin is expected to account for a major portion of the future water requirements. Therefore,

the future municipal and industrial water requirements have been projected on an urban per capita basis plus the expected Trenton Foods, Inc. requirements.

The present per capita water use in the basin is approximately 80 gallons per capita per day (gpcd) with the average use in most municipalities ranging from 65 to 85 gpcd. This rate is expected to increase to 150 gpcd in 2010 and 200 gpcd in 2060 as water uses increase in domestic uses, in industrial activity, and in the available dependable supply following construction of the proposed system in the basin.

With the increase in dependability of the stream supply following construction of the proposed reservoirs, communities now using poor quality ground water may be expected to use the better quality water downstream from the reservoirs.

At present, the total municipal and industrial water use in the basin is 6.2 cubic feet per second (cfs) or approximately four million gallons per day (mgd). By the year 2010, it is expected that the demand will have increased to 19 cfs (12.7 mgd) and in 2060, the projected demand is expected to reach 40 cfs (26.7 mgd).

Considering the inadequacy and poor quality of the ground water in the area and the accessibility of the communities to the system of reservoirs, it is anticipated that the municipal and industrial water requirements from the system of reservoirs will be 8 cfs (5.3 mgd) in 2010 and 19 cfs (12.7 mgd) by the year 2060.

Value of Storage

It was determined that the present municipal and industrial requirements

in the Grand River Basin could be met without additional storage in the proposed Federal impoundments.

The conservation allocation in the proposed reservoirs is large enough that if at some future date the communities of the basin desire to purchase some storage, there will be sufficient storage space available.

VIII. STREAMFLOW REGULATION FOR QUALITY CONTROL

Present Uses

The Grand River and its tributaries are used as sources of water supplies and to carry sewage plant effluents.

Organic waste loadings in the Grand River and its tributaries are primarily from the municipalities in the basin. The municipalities have a total untreated sewage of approximately 70,000 P.E. (BOD), and after treatment discharge approximately 16,000 P. E. Trenton, Missouri is the largest single waste contributor in the basin with untreated wastes totaling 18,000 P. E. and after treatment discharges 4,000 P. E. to the Thompson River. See Exhibit No. 5 for "Basic Data on Sources of Pollution - Grand River Basin".

Prospective Uses

The reservoirs will be used for flood control, municipal water supply, and streamflow regulation for quality control, and will contribute to expansion of recreational opportunities, and preservation of fishing and hunting values in a large area.

Streamflow regulation for quality control was based on maintaining a minimum level of 5 ppm oxygen in accordance with the objectives of the Missouri Engineering Health Council. The mineral concentrations of the water in the Grand River basin are low and no streamflow regulation will be required to control concentrations. It was assumed that all municipalities will have a minimum of secondary treatment followed by chlorination for bacteriological control where necessary. Chemicals such as herbicides,

pesticides, etc. are assumed to be properly applied and no allowances were made for dilution of these pollutants.

The following assumptions were made in estimating the streamflow regulation required:

1. Waste discharges will continue to be mainly organic.
2. Maintenance of 5 ppm oxygen in accordance with the objectives of the Missouri Basin Engineering Health Council.
3. All seven of the proposed reservoirs will be constructed.
4. The water temperature was assumed to be 24° C. during a five month summer period, 15° C. for three months during the spring and fall periods, and 5° C. during a four month winter period.

In the determination of the needs for the regulation of streamflows for water quality control, all wastes in the study area were considered to be adequately treated. At the present time, a sustained flow of 25 cfs would be required for quality control. Total sustained flows to provide satisfactory quality in 2010 and 2060 are expected to be 55 cfs and 97 cfs, respectively. Because of the seven reservoir system, individual sustained flow requirements were developed and are presented below:

Reservoir	Flow Location	Flows Required in CFS 1960	2010	2060
Pattonsbury	G-96 to G-64	1.5	2.5	3.5
Mercer	W-35 to W-0	<1.0	<1.0	<1.0
Braymer	SC-19 to SC-0	<1.0	1.0	1.0
Trenton	T-26 to T-0	18.0	28.0	42.0
Brookfield	YC-24 to YC-0	3.0	10.0	14.5
Linneus	LC-21 to LC-0	<1.0	<1.0	<1.0
St. Catherine	EYC-12 to EYC-0	<1.0	<1.0	<1.0
Main Stem*	G-64 to G-0	<1.0	14.5	30.0

*The main stem requirements for the section G-64 to G-0 can be drawn from one of several of the proposed reservoirs. Main stem requirements for the stretch from G-64 to G-0 takes into account the re-availability of a portion of the Trenton and Pattonsburg releases.

Value of Storage

The present evaluation is a conservative estimate of the attributable benefits, as such aspects as the use of these streams by the populace of the metropolitan areas of St. Louis and Kansas City for recreational purposes and the stabilizing effect of regulated flows on the Missouri River quality were not evaluated in monetary benefits.

A 10 percent chance that there will be a deficiency in reservoir outflow in any year was considered to be a reasonable level of protection of esthetic values, environmental safety, and preservation of a desirable aquatic regime in the waters of the basin to promote continued recreational

use and development.

Due to the lack of ground water in the basin and other sources of supply which would be economically feasible to develop to provide adequate water, it was determined that values for storage in the proposed reservoir system in the Grand River Basin would be based on the cost of the alternative of single-purpose reservoirs.

The minimum sustained flows requested in the streams of the Grand River Basin are small in relation to the amounts of water which could be furnished from storage in the proposed reservoirs. For this reason, it was necessary to develop the benefit figures from cost-capacity curves for sites on the smaller tributary streams.

The storage required to provide quality control flows for the present and to 100 years in the future was determined and the value of this storage was computed and reduced to its present value. Based on the 2-7/8 % interest rate used on Government projects and on the storage space required in them to provide water for streamflow regulation for quality control, the annual costs have been determined and are presented in Table No. VIII-1.

Table No. VIII-1

Value of Storage for Streamflow Regulation

Reservoir	Annual Value*
Partonsburg	13,980
Mercer	9,830
Braymer	22,010
Trenton	62,520
Brookfield	27,860
Linneus	0
St. Catherine	0

*Based on 100 annual payments at 2 7/8 percent interest.

GRAND RIVER BASIN

FIGURE 1

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XI. APPENDIX

Exhibit No. 2

Historical Streamflows in the Grand River Study Area 1/

Station	Location	River Mile*	Years of Record	Flows in cfs		
				Maximum	Minimum	Average
East Fork of Big Creek near Bethany, Mo.	Upstream 4 miles from Bethany	BC-24 G-108	26	8,120	0	46.7
Grand River near Gallatin, Mo.	Upstream 6 miles from Honey Creek	G-90	39	69,100	2.2	1,082
Thompson River at Davis City, Iowa	5¼ miles upstream from State Line	G-64 T-71	25	21,300	0.1	346
Weldon River near Leon, Iowa	6.5 miles southeast of Leon	G-64 T-28, W-41	2	48,600	0.7	-
Weldon River at Mill Grove, Mo.	County Highway Bridge in Mill Grove	G-64 T-28, W-18	31	46,000	0	238
Thompson River at Trenton, Mo.	1.75 miles downstream from Weldon River	G-64 T-26	34	95,000	1	860
Shoal Creek near Braymer, Mo.	6 miles north of Braymer	SC-19 G-58	3	7,840	0	-
Medicine Creek near Galt, Mo.	2 miles upstream from West Medicine Creek	G-50 MC-32	39	24,200	0	135
Locust Creek near Linneus, Mo.	5 miles downstream from W. Locust Creek	G-42 LC-25	32	38,000	0	326
Grand River near Sumner, Mo.	2½ miles downstream from Locust Creek	G-40	37	180,000	10	3,626
West Yellow Creek near Brookfield, Mo.	1½ miles below Bear Creek	G-32 YC-24	1	3,900	0	-
Grand River at Missouri River 1/		M-251.7	-	-	-	4,230
Missouri River at Kansas City		M-379				

*River miles are approximate

1/Data are from Geological Survey Water Supply Paper 1710, Part 6, "Surface Water Supply of the United States, 1960".

Exhibit No. 3

Municipal Water Supplies
Grand River Basin

County	City	Pop. 1960	Water Treatment	Source of Supply	M.G. Impounded Storage	MGD Maximum Draft	Avg. Plant Output mgd	GPCD
Iowa								
Union	Afton	773	Coagulation, Chlorination Filtration, Sedimentation	Impoundment Dug Well			0.059	76.3
Wayne	Allerton	693	Chlorination, Aeration, Odor Removal, Softening Filtration	Impoundment			0.080	115.6
Adair	Greenfield	2,243	Aeration, Chlorination Coagulation, Odor Removal	Impoundment			0.137	61.1
Decatur	Leon	2,004	Chlorination	Deep Wells		0.259	0.074	36.9
Decatur	Lamoni	2,175	Coagulation, Odor Control, Filtration, Chlorination	Impoundment			0.137	63.0
Ringgold	Mt. Ayr	1,738	Aeration, Softening, Odor Removal, Sedimentation, Filtration, Chlorination	Impoundment			0.120	69.0
Missouri								
Gentry	Albany	1,662	Softening, Chlorination, Filtration	Wells		0.420	0.128	77.0
Harrison	Bethany	2,771	Coagulation, Sedimentation, Filtration, Chlorination	Impoundment			0.180	65.0
Caldwell	Braymer	874	Aeration, Iron Removal, Sedimentation, Filtration	Wells		0.144	0.025	28.6
Linn	Brookfield	5,694	Coagulation, Sedimentation, Filtration, Chlorination	Impoundment	106.0		0.370	65.0
Linn	Browning	412	Iron Removal, Chlorination	Wells		0.216	0.080	194.2
Chariton	Brunswick	1,493	Iron Removal, Chlorination	Wells		0.491	0.090	60.3
Clinton	Cameron	3,674	Aeration, Sedimentation, Filtration, Softening, Chlorination	Impoundment	278.0		0.125	33.2

Exhibit No. 3

Exhibit No. 3
(cont'd)

Municipal Water Supplies

Grand River Basin

County	City	Pop. 1960	Water Treatment	Source of Supply	M.G. Impounded Storage	MGD Maximum Draft	Avg. Plant Output mgd	GPCD
Missouri								
Livingston	Chillicothe	9,236	Softening, Sedimentation, Filtration, Chlorination	Grand River			0.728	78.9
Daviess	Gallatin	1,658	Aeration, Sedimentation, Softening, Chlorination	Wells		0.260	0.085	51.3
Worth	Grant City	1,061	Aeration, Filtration, Chlorination	Wells		0.500	0.075	70.7
Caldwell	Hamilton	1,701	Coagulation, Filtration, Sedimentation, Chlorination	Impoundment	190.0		0.130	76.4
Linn	Linneus	471	Coagulation, Filtration, Sedimentation, Chlorination	Impoundment	25.0		0.026	55.2
DeKalb	Maysville	942	Aeration, Coagulation, Filtration, Chlorination	Impoundment	90.0		0.084	89.2
Linn	Meadville	447	Aeration, Coagulation, Filtration, Chlorination	Impoundment	0.144		0.022	49.2
Chariton	Mendon	287	Aeration, Filtration, Chlorination	Wells		0.328	0.022	76.7
Sullivan	Milan	1,670	Aeration, Softening, Chlorination, Sedimentation, Filtration	Impoundment	197.0		0.125	71.9
Mercer	Princeton	1,443	Aeration, Filtration, Chlorination	Wells		0.420	0.125	83.2
Harrison	Ridgeway	470	None	Wells		0.06	0.007	14.9
Grundy	Spickardsville	450	Aeration, Filtration, Chlorination	Ground				
Gentry	Stanberry	1,409	None	Wells		0.220	0.090	63.9
Grundy	Trenton	6,262	Coagulation, Sedimentation Filtration, Chlorination	Grand River and Aux. Impoundment	90.0		1.000	159.7
		51,537					3.977	77.2

Exhibit No. 3 (2)

X-1-C

Exhibit No. 4

Typical Chemical Values of Municipal Water Supplies (ppm)

Grand River Basin

Cities	Treated or Raw	Total Dis. Solids	Chlorides (Cl^-)	Sulfates (SO_4)	Nitrate (N)	Hardness ($CaCO_3$)	Iron (Fe)	Source of Supply
Missouri								
Albany	Treated	304	12.1	42.0	0.06	208.0	0.45	Wells
Bethany	Treated	218	10.4	41.8	0.09	140.0	0.03	Imp.
Braymer	Treated	469	27.6	9.5	0.16	236.0	0.25	Wells
Brookfield	Treated	333	9.5	96.9	0.06	186.0	0.06	Imp.
Browning	Treated	394	28.9	62.6	0.09	214.0	0.08	Wells
Brunswick	Treated	535	79.5	57.0	0	350.0	0.7	Wells
Cameron	Raw	358	17.6	76.8	0.85	232.0	0.3	Imp.
Chillicothe	Treated	151	9.1	62.8	0.92	78.0	0.01	G.River
Gallatin	Raw	351	6.8	91.1	0.23	236.0	2.0	Well
Grant City	Treated	333	20.3	43.8	0	199.0	1.6	Wells
Hamilton	Treated	231	9.1	87.0	0.35	120.0	0.02	Imp.
Linneus	Treated	264	16.3	75.5	0.05	154.0	0.02	Imp.
Maysville	Treated	249	15.4	48.1	0.07	160.0	0.03	Imp.
Meadville	Treated	569	27.7	25.5	0.14	272	0.7	Wells
Mendon	Raw	473	55.4	32.1	0	220.0	2.8	Wells
Milan	Raw	217	13.1	45.2	0.5	135	0.04	Imp.
Princeton	Raw	304	11.4	44.6	0	198.0	20.0	Well
Ridgeway	Raw	5,125	1,152.3	1,650.0	0	38.0	1.2	Deep Well
Spickard	Raw	521	15.3	184.6	0.06	287.0	2.5	Well
Stanberry	Raw	1,496	95.3	572.8	0.28	492.0	0.4	Well
Trenton	Treated	306	10.4	60.7	0	226.0	0.03	Reservoir
Trenton	Raw	258	5.6	42.2	0.58	194.0	0.8	Reservoir
Iowa								
Afton	Treated	90	7.0	29.4	0.2	90.0	0.08	Reservoir
Allerton	Treated	255	11.5	94.6	0.6	156	0.06	Reservoir
Greenfield	Treated	237	8.0	40.3	0.4	149	< 0.02	Reservoir
Lamoni	Treated	170	9.0	51.4	0.2	56.0	0.12	Reservoir
Leon	Raw	2,684	170	1,150	1.3	445	5.95	Deep Well
Mount Ayr	Treated	276	9.5	71.4	1.0	118	< 0.02	Reservoir

Exhibit No. 5

Basic Data On Sources of Pollution
Grand River Basin

Municipality or Industry	River Miles Above Mouth	Sewered Population	P.E.(BOD) before Treatment	Nature of Waste	Treatment Provided	P.E. (BOD) Discharge to Watercourse
Grand River						
State Line (Ia.-Mo.)	176					
Wildcat Creek	147					
Stanberry, Mo.	147-5	1,115	1,115	Domestic	Secondary	111
Grand River						
Middle Fork	142					
Mt. Ayr, Iowa	142-41	1,400	1,400	Domestic	Secondary	250
State Line (Ia.-Mo.)	142-25					
Grant City, Mo.	142-18-4	260	260	Domestic	Primary	175
East Fork	142					
Albany, Mo.	142-41-3	1,551	1,661	Domestic	Secondary	150 *
Grand River						
Grindstone Creek	112					
Lost Creek	112-10					
West Fork Lost Creek	112-10-5					
Maysville, Mo.	112-10-5-4	700	700	Domestic	Secondary	100
Grand River						
Big Creek	113					
Bethany, Mo.	113-24	1,700	3,355	Domestic	Primary	2,180
Grand River						
Big Creek	108					
Seven Mile Creek	108-20					
Lamoni, Iowa	108-20-33	1,900	4,300E	Domestic & Industrial	Secondary	2,000E

* The Plant is presently inoperable (February 1963) and the plant discharge is 1661 P.E.

Exhibit No. 5

XI-E

Basic Data On Sources of Pollution (cont'd)
Grand River Basin

Municipality or Industry	River Miles Above Mouth	Sewered Population	P.E.(BOD) before Treatment	Nature of Waste	Treatment Provided	P.E. (BOD) Discharge to Watercourse
Grand River						
Gallatin, Mo.	90	1,300	1,300	Domestic	Secondary	210
Grand River						
Lick Fork	83					
Hamilton, Mo.	83-12	1,500	1,500E	Domestic	Lagoon	150E
Grand River						
Thompson River	64					
Nine Mile Creek	64-131					
Greenfield, Iowa	64-131-9	1,600	2,300	Domestic & Industrial	Secondary	500E
Thompson River	64					
Twelve-Mile Creek	64-98					
Afton, Iowa	64-98-14	600	600	Domestic	Septic Tank	400E
Afton Creamery	64-98-14	N.A.	900E	Creamery	Septic Tank	900E
Thompson River	64					
State Line (Ia.-Mo.)	64-66					
Weldon River	64-28					
Little River	64-28-35					
Leon, Iowa	64-28-35-24	1,800	2,400	Domestic & Industrial	Secondary	300E
Weldon River	64-28					
Princeton, Mo.	64-28-30	1,100	1,100E	Domestic	Lagoon	110E
Thompson River	64					
Trenton, Mo.	64-26	2,800	16,000	Domestic &Industrial	Secondary	4,000
Trenton, Mo.	64-26	1,700	1,700	Domestic	Lagoon	170

Exhibit No. 5 (2)

XI-F

Exhibit No. 5 (cont'd)

Basic Data On Sources of Pollution (cont'd)

Grand River Basin

Municipality or Industry	River Miles Above Mouth	Severed Population	P.E.(BOD) before Treatment	Nature of Waste	Treatment Provided	P.E. (BOD) Discharge to Watercourse
Grand River						
Chillicothe, Mo.	64-1	8,000	11,000	Domestic & Industrial	Secondary	1,100
Grand River						
Shoal Creek	58					
Lathrop, Mo.	58-65	745	990	Domestic	Secondary	225
Branch of Shoal Creek	58-50					
Cameron, Mo.	58-50-5	2,600	2,600	Domestic	Secondary	300
Grand River						
Medicine Creek	50					
Allerton, Iowa	50-32-45	600	3,750	Domestic & Industrial	Secondary	1,500
State Line (Ia.-Mo.)	50-67					
Grand River						
Locust Creek	42					
East Locust Creek	42-30					
Milan, Mo.	42-30-44	1,200	5,500	Domestic & Industrial	Lagoon	550
Grand River						
Yellow Creek	32					
Ditch	32-3					
Brookfield, Mo.	32-3-20	4,200	4,400	Domestic	Secondary	440
Grand River						
Brunswick, Mo.	5	1,300	1,300	Domestic	Lagoon	130
		39,671				

Exhibit No. 5 (3)

XI-2

cc: 10 cys to Dist. Eng. KC District
1 cy to CBC, Greeley - Attn: Rainey
1/7/64 lrc